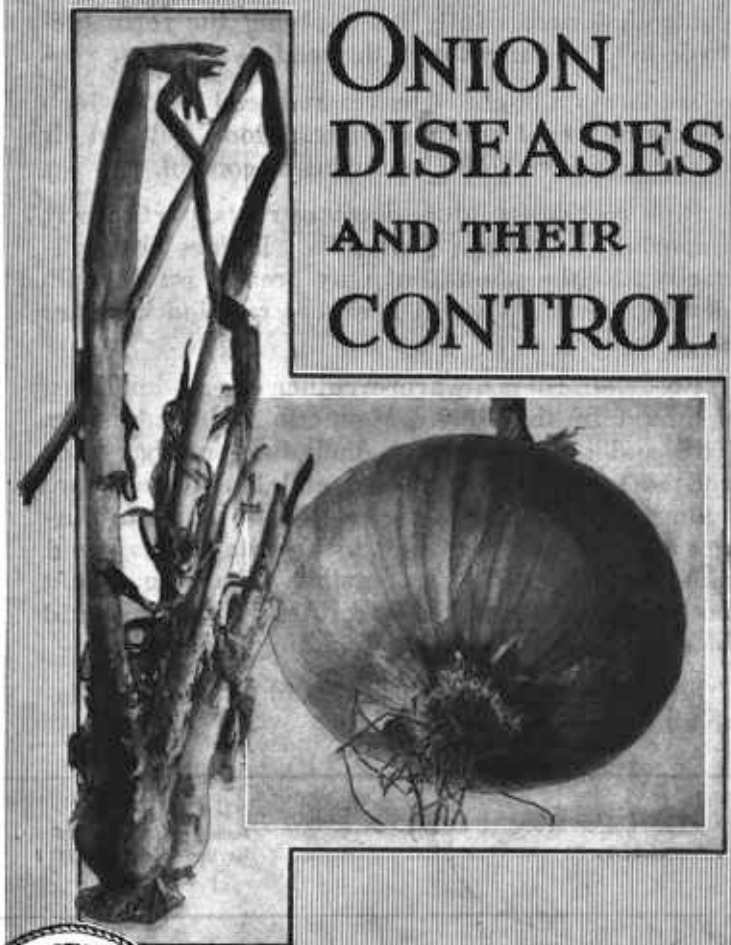
U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1060



ONION DISEASES AND THEIR CONTROL

ONION SMUT kills the young seedlings in the spring, is common in old sections, but can be controlled successfully by applying the formaldehyde-drip treatment with the seed.

Mildew is a blight of leaves and seed stems which occurs in a cool humid climate. Good soil and air drainage are essential as means of control.

Pink root is a gradual decay of roots, particularly important in certain peat soils. It does not ordinarily kill the plants but may greatly retard bulb development. When it is severe rotation becomes necessary.

Fusarium rot is a warm-weather disease and most common in the Rocky Mountain irrigated areas. This and other bulb rots, including smudge, neck rot, soft rot, purple blotch, and black mold, are reduced by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible. Bruising should be avoided and bruised and diseased bulbs should be discarded rigidly in the handling operations.

Storage conditions at 32° F. and 65 percent relative humidity are best.

Washington, D. C.

Issued November 1919
Revised December 1937

ONION DISEASES AND THEIR CONTROL

By J. C. WALKER, *agent, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, and professor of plant pathology, University of Wisconsin*

CONTENTS

INTRODUCTION

THE ANNUAL ONION CROP in the United States consists of about 25,000,000 bushels, grown on some 85,000 acres and valued on the farm at $10,000,000 to $15,000,000. Onion culture is intensive, and the growing of the crop entails heavy investment in land, fertilizer, and labor. It is one of the few crops in which repeated croppings, or very short rotations, is commonly practiced. Individual growing areas are thus relatively small and concentrated, but they are not limited geographically, since intensive onion-growing sections are to be found in most States. The 10 States leading in total production are Texas, Michigan, New York, California, Indiana, Massachusetts, New Jersey, Ohio, Colorado, and Minnesota.

Areas producing the table crop may be divided into two groups, namely, (1) those in the northern half of the country, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States from Florida to southern California, in which a winter or spring crop is grown.

In the northern areas most of the crop is grown from seed sown directly in the field in early spring at the rate of 3 to 5 pounds per acre. No thinning of stand is made after sowing. Both upland and muck soils are used, but in recent years the acreage has increased rapidly on muck until now it comprises the greater portion. The common varieties are Yellow Globe, White Globe, Red Globe, and Yellow Danvers in the East and Midwest, with additional varieties

such as Australian Brown in California. In the Rocky Mountain areas on irrigated alluvial soils the Sweet Spanish varieties are grown extensively. In the midwestern and eastern areas relatively small acreages of earlier onions are grown from sets. These are flat varieties such as Yellow Strassburg, Ebenezer, Red Wethersfield, White Portugal, and the oblong bulb variety Yellow Bottleneck. Most of the northern crop is carried in storage for varying periods and is placed on the consuming market throughout the country up to March and April.

The southern crop is grown in part from northern-grown sets of the Yellow Strassburg, Ebenezer, Red Wethersfield, and White Portugal varieties. The bulk of the crop, however, is of the very flat, mild-flavored Bermuda type, chiefly Yellow Bermuda, Crystal Wax, and to a limited extent Creole. The seed is sown in late summer and early autumn in seedbeds, whence plants are set during midwinter months. Much of the acreage is under irrigation. The crop matures in April and May. These southern crops thus supply the consuming markets throughout the country during April, May, June, and July and are followed by the earliest northern onions grown from sets. The Bermuda type is not adapted to long storage and the marketing season of this crop is thus much shorter than that of the northern crop.

Onion sets are chiefly of the Red Wethersfield, Yellow Strassburg, Ebenezer, and White Portugal varieties. They are grown in several Northern States, always on upland or alluvial soil. The majority is produced in the Chicago area extending from northwestern Indiana, through northeastern Illinois and southeastern Wisconsin. The seed is sown in early spring, as in table onions, but at the rate of 75 to 80 pounds of seed per acre. Some of the crop is shipped south immediately after harvest for fall planting; most of it is stored and shipped during the winter and throughout the spring. Onion sets are widely distributed and used generally for spring bunching onions in the home garden and on the commercial truck farm.

Onion seed was formerly grown chiefly in Connecticut, New York, and Ohio. Most of it is now produced in California, where summer-matured bulbs are planted in the autumn and seed plants grow during the winter to flower and mature during the dry summer. Seed of the Bermuda type is grown almost exclusively in the Canary Islands.

It may be seen from this brief survey of the onion industry that the crop is grown under a variety of climatic conditions and on a wide range of soils. As environmental factors have a direct bearing upon disease, the preeminent diseases vary with geography. In the following discussion of diseases, reference will be made repeatedly to specific growing regions and cultural practices.

DESCRIPTIVE KEY TO ONION DISEASES

The following key of the outstanding symptoms of onion diseases will aid in their recognition:

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings (fig. 1)---------- Smut, page 3

2. Rapid death of young seedlings in circular patches in the field ..... Damping-off, page 7
3. The leaves, beginning at the tips, turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later (fig. 6) ..... Mildew, page 7
4. A black moldy growth on leaf tips or seedstalks, often following mildew or purple blotch ..... Leafmold, page 9
5. Large purple lesions, sometimes showing zonation, eventually girdling leaves and seedstalks ..... Purple blotch, page 9
6. A rapid dying-back from the tips of the leaves, accompanied by a rot starting at the base of the bulb (fig. 7) ..... Fusarium rot, page 11
7. A condition of the tops quite similar to fusarium rot but differing in that round black bodies about the size of poppy seeds appear in the diseased bulb (fig. 8) ..... White rot, page 12
8. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant ..... Pink root, page 10
9. Orange or golden-yellow pustules appear on leaves or seed stems, especially on those of the Egyptian onion ..... Rust, page 11
10. Pronounced stunting accompanied by various degrees of yellowing ..... Yellow dwarf, page 13
11. Creeping or twining leafless plants attack leaves of onions, often killing the tops in roughly circular areas in the field (fig. 9). Dodder, page 15
12. The leaves become a sickly green; swellings form on the roots (fig. 10) ..... Root knot, page 15

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard black kernels later appear on the surface of affected scales (figs. 11 and 12) ..... Neck rot, page 18
2. A rot begins at harvesttime or later, but differs from neck rot in that it is softer and more watery, usually with a very offensive odor (fig. 13) ..... Soft rot, page 20
3. A semiwatery rot advancing from the base of the scale upward (fig. 7) ..... Fusarium rot, page 11
4. Black powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of the scales or between them (fig. 14) ..... Black mold, page 21
5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses, appear shortly before harvesttime on the outer scales, primarily on white varieties (fig. 15) ..... Smudge, page 22
6. A semiwatery decay, at first deep yellow, then wine red, and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture ..... Purple blotch, page 9
7. Dry decay of garlic, with brown kernellike bodies in and on decay tissue ..... Aspergillus rot, page 23

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Smut is a disease in which the causal organism remains viable in the soil for many years. Smut-infested soil is therefore likely to remain so indefinitely and is found usually in areas where onions have been grown intensively for a long time. This disease is to be found in many onion regions in the Northern States from coast to coast. It is not a factor in the winter-growing southern regions, where its almost complete absence is due largely to climatic conditions.

CHARACTERISTICS

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves,

the latter usually being slightly thickened and often curved downward abnormally. These blisters often break open, exposing black powdery masses which are made up of the spores of the causal fungus. A majority of the infected seedlings die within 3 to 5 weeks after germination. Such thinning of the stand is thus an early and important feature of smut injury, although a small percentage of infected seedlings outgrow the disease. Some diseased plants survive until midseason or harvest, new leaves and scales becoming infected as they develop. Figure 1 shows a half-grown infected plant which has survived the seedling stage. Such plants usually produce bulbs so small and imperfect that they are thrown out at harvest. Occasionally, infected bulbs are large enough and so slightly affected as to escape notice and reach warehouse and market. Such specimens are characterized by slightly raised brown to black pustules most prevalent near the base of the outer fleshy scale and occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

FIGURE 1.—Onion smut. A half-grown plant showing brown to black unbroken blisters in the scales and leaves. When the blisters or pustules break open the black powdery masses of spores of the smut fungus are exposed.

THE CAUSAL ORGANISM

The fungus parasite (*Urocystis cepulae*), associated with onion smut, infects only the onion and certain closely related species of plants such as leek, Welsh onion, and wild forms. Most varieties of the Welsh onion are resistant to the disease. The black powdery masses which are exposed upon the splitting of the blisters or pustules in the onion leaf consist of myriads of spores or seed bodies which propagate the fungus. These spores are highly resistant to environmental changes, and as they become incorporated in the soil they remain viable for many years. This is the reason that continuous cropping is favorable to the accumulation of the fungus and that soil once infested remains so indefinitely.

The spores germinate by sending out fungus threads which permeate the soil and often break up into innumerable secondary spores. These stages of the fungus survive only for short periods and are sensitive to cold and drought. The threads penetrate young onion

seedlings and, taking nourishment from the plant, form the characteristic blisters within the tissue, finally climaxing in the development of more dark spores.

Important to the understanding of onion smut and its control is the fact that the fungus can invade the onion plant only in the early seedling stage. If the outer seedling leaf (cotyledon) escapes infection until it is mature (about 3 weeks from germination), no further invasion occurs even in very heavily infested soil. This is the reason why smut is not a disease factor when the crop is started from sets or slips (seedling transplants), even though they are set in smutty land. When the mean soil temperature is 84° F. or above during the period of the seedlings' susceptibility, no infection occurs, because the fungus is inactive at this high temperature. At slightly lower temperatures the seedlings tend to outgrow the disease more effectively than in cool soil. These temperature relations explain the

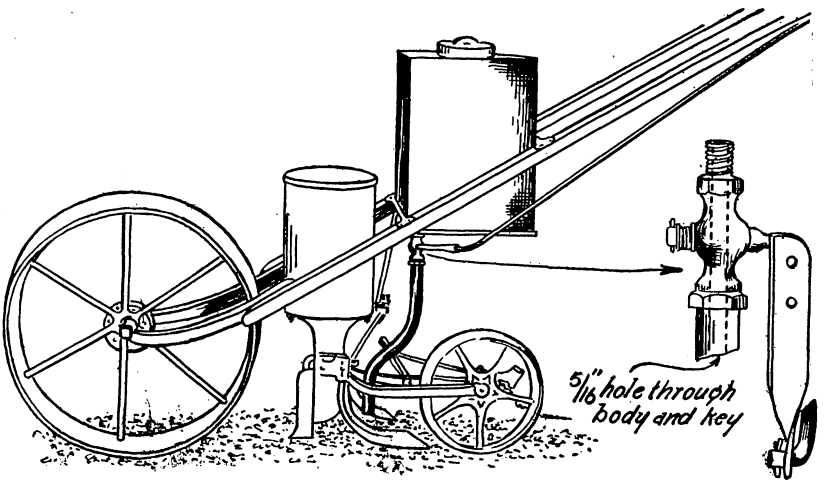


FIGURE 2.—Single-row onion seeder equipped with a formaldehyde-drip attachment for onion-smut control. Note that the disinfectant is introduced into the furrow just after the seed is dropped and before the furrow is covered. The cut-off valve is regulated from the handle of the seeder.

absence of the disease on the southern onion crops where the seed is sown in late summer. The seedlings are thus started off in very warm soil, which is unfavorable to smut. In the main crop of the Northern States the seedlings come up in cool soil, and the smut fungus, if present, is not inhibited.

The spores of smut are spread locally by farm implements, by the feet of men and animals, by surface drainage water, and by airborne soil. The transfer from locality to locality is rarely made through the medium of seed, but commonly by means of onion sets grown on smutty soil.

CONTROL

As stated above, the crop started with sets or slips is not affected. In the main crop of the North, started from seed in the field, the disease is controlled by the formaldehyde-drip method. This consists of the application of a stream of dilute formaldehyde in the

furrow with the seed. The vapor of the formaldehyde permeates the soil in the area between the seed and the soil surface sufficiently to disinfect it temporarily insofar as smut is concerned. The young

FIGURE 3.—A six-row seeder equipped with the formaldehyde drip attachment for smut control.

FIGURE 4.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has resulted in the death of a large percentage of the plants in the two untreated rows in the center; the remainder of the field has practically a full stand.

seedling is thus protected during its susceptible period. The effectiveness of the treatment is sometimes reduced if heavy rain follows immediately after sowing; however, a lapse of 24 hours without rain usually insures successful control.

The attachments of formaldehyde tanks to single-row seeders and to horse-drawn gang seeders are shown in figures 2 and 3. The effect of the treatment on stand and yield is shown in figures 4 and 5.

There is some latitude in the strength of the formaldehyde solution and the rate of application. When 14-inch rows are planted, the best results have been secured with a solution made from 1 pint of concentrated formaldehyde to 16 gallons of water, applied at the rate of 200 gallons per acre. Almost as effective results were secured with a solution of 1 pint to 8 gallons of water, applied at the rate of 100 gallons per acre. The latter formula is now the more commonly used. The cost of materials and extra labor is about $3 per acre.

FIGURE 5.—Yield of a treated and of an untreated row of onions in the field shown in figure 4. The treated rows averaged 545 bushels; the untreated ones 200 bushels per acre.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly, since a stream of liquid in each individual row is essential.

DAMPING-OFF

Damping-off is a disease common to seedlings of many plants. One or more of several soil fungi may be involved. When seedlings are growing rapidly they are subject to attack by these fungi, whereas they are resistant at other times. The plants are attacked at or slightly below the soil line, and the tissue shrinks rapidly while the still turgid above-ground parts topple over. Damping-off in onions does not ordinarily take the form of thinning out plants here and there, but more often kills practically all plants in roughly circular areas variable in size. There is no specific remedy for this disease. The best cultural practices, such as frequent cultivation, good drainage, and good fertility, all discourage damping-off by providing the most favorable growing conditions for the onion plant.

MILDEW

Onion mildew has been reported from most States where onions are grown. Its destructiveness varies widely with locality and season. Relatively cool, moist weather is most favorable for its development. Losses are most severe on the bulb crop in New York, Oregon, and Michigan. In California losses in the seed crop during the winter and spring are sometimes heavy, since the foggy weather is especially favorable to the mildew which attacks the seedstalks, causing them to fall over before the seed is mature.

19066°—37——2

CHARACTERISTICS

The first symptoms are found most realiy by examining leaves closely in the early morning while the dew is still present. The violet furry growth on the surface of the leaf or seed stem is characteristic. The affected leaves gradually become pale green and later yellowish, and the diseased portions collapse. The furry growth becomes more widespread if the humidity remains high, but the advance and spread is very dependent on favorable weather. The disease commonly starts in spots in the field and spreads to surrounding areas. If the weather remains dry following an outbreak, plants send out new leaves and partially recover, but on the return of humid conditions the fungus revives and new plant growth becomes blighted. Repeated killing of leaves in this manner reduces growth, and the bulbs remain small, while the necks are unduly succulent and subject to attack by storage-decay organisms. Lesions on onion-seed stems are circular or elongate, often affecting only one side of the stalk, but weakening the latter and causing it to break over from the weight of the seed umbel. This causes shriveling of the seeds. The fungus may infect the flower parts as well, and there is circumstantial evidence that it is carried with the seed (fig. 6).

FIGURE 6.—Onion mildew. Note the fungus growth on the dying older leaves; the two youngest leaves are not affected as yet. The furry masses (mildew) on the diseased leaves consist of fruiting branches of the causal fungus and many thin-walled light microscopic spores, which are readily disseminated by the wind.

THE CAUSAL ORGANISM

The causal organism (*Peronospora destructor* (Berk.) Caspary) is closely related to those associated with potato late blight, grape mildew, and cucumber downy mildew. The onion fungus is confined largely to onion, Welsh onion, and chives. Garlic and leek have been reported as hosts, but it is not certain that they are subject to infection by the same strain as onion. The furry masses on the affected parts of the plant are made up of branches of the fungus which extend above the surface and bear numerous microscopic spores. These spores are thin-walled and light; they are easily detached and transported by air currents, and this is the chief means whereby the fungus is disseminated locally. They are short-lived, however, and very sensitive to drying. If moist

weather favorable to infection does not prevail, most of them die without causing infection.

When damp weather prevails, the spores germinate promptly, and if this occurs on the leaf surface the germ tube growing into a thread enters through a breathing pore (stomate) and into the internal tissue. As the fungus absorbs food from the onion the cells of the latter gradually succumb; as a result the leaves turn yellow, shrivel, and die. The fungus sends fruiting branches to the surface, where it produces more spores.

Another type of spore, the resting spore or oospore, is formed in the dying plant tissues. This has a thick wall and a concentrated food supply and is suited to withstand unfavorable environment. The internal threads or mycelium also survive long periods, especially when they get into the bulb before it matures. Oospores and mycelium may be carried with the seed. Thus the fungus lives over unfavorable periods as oospores or as mycelium in bulbs and sets, in seed, and in the soil, and may be transported long distances with bulbs and seed.

CONTROL

While many downy mildews such as grape mildew and potato late blight are successfully controlled by spraying with bordeaux mixture, this has never proved to be the case with onion mildew. One drawback is the great difficulty in securing thorough coverage of the very waxy foliage. A second handicap is the continual emergence of new leaves from the neck, necessitating very frequent applications for complete protection.

In regions where mildew occurs frequently cultural practices are about all that can be applied to reduce losses, and these are not wholly effective. Burning refuse to reduce the carry-over of the resting spores and mycelium is advised, and continuous cropping to onions should be avoided. Adequate seed-treatment methods have not been devised as yet. Onions should not be planted in fields with poor air drainage. Good soil drainage, frequent cultivation of the crop, and adequate fertility all help by providing favorable conditions for plant growth. Cultivating the crop while dew or rain is still on the foliage is not advisable.

LEAFMOLD

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a secondary fungus (*Thyrospora parasitica*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seedstalks following either the mildew or the purple blotch.

PURPLE BLOTCH

Purple blotch is a disease of leaves, seedstalks, and bulbs. It has been commonly confused with leafmold because this organism commonly follows purple blotch as a secondary invader. However, unlike the leafmold organism, the purple blotch organism is capable of invading the onion plant quite independently of any forerunner. The

disease is of some importance on the seed crop and sometimes causes appreciable losses as a bulb rot. The causal organism appears to be rather widespread in occurrence.

CHARACTERISTICS

The disease appears first as small, whitish, sunken lesions with purple centers that rapidly enlarge and eventually girdle the leaf or stalk. About 2 or 3 weeks after its first appearance, darkened zones, consisting of superficial masses of fungus spores, appear on the lesion. Usually the affected leaves or stalks fall over and die within 3 or 4 weeks after lesions appear, if the environment is favorable for disease development. Purple blotch requires less humid weather than mildew; thus it is much less limited in geographic distribution.

The bulbs are attacked at harvesttime. The fungus invades most commonly through the neck, but may invade wounds on the fleshy scales. The decay is at first semiwatery and is made especially conspicuous by the color associated with it. The parasite secretes in abundance a pigment which diffuses through the scale tissue somewhat in advance of the fungus threads. Affected tissue is deep yellow at first, turning gradually to a wine red. With the profuse development of dark-colored fungus threads, the older decayed tissue eventually becomes dark brown to black. As the tissue becomes desiccated the diseased scales eventually dry down to a papery texture. Often only one or two outer scales are affected; in other instances, notably with white bottom sets, the entire bulb may be destroyed.

THE CAUSAL ORGANISM

The causal fungus (*Macrosporium porri* Ell.) is closely related to that associated with early blight of potato and tomato. It is confined, however, to onion and possibly such closely related plants as leek and chives. The spores, which are produced on short fruiting branches on the surface of the decayed leaves, stems, and scales, are many-celled, dark colored, and capable of withstanding unfavorable environment; thus they carry the fungus through northern winters or hot southern summers. They germinate to produce fungus threads (mycelium) that invade the stomates of leaves and the stems and wounds on the bulbs.

CONTROL

No satisfactory control measures for the disease on leaves and stems have been devised. The practices described for the control of onion neck rot (p. 18) are recommended for the bulb rot.

PINK ROOT

Pink root is serious in the delta region of California, in the Rio Grande Valley of Texas, and in muck-soil districts of New York, Ohio, and Indiana.

The symptoms become manifest in the seedbed or after transplanting. Affected roots shrivel and die, meanwhile taking on a distinctly

pink color. Abnormal yellowing of the roots is commonly associated with pink root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and, although the affected plants are commonly not killed by the disease, the reduced food supply results in the formation of mere scallions or small bulbs. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvesttime in the small size of the bulbs, varying with the severity of the attack.

The fungus which causes pink root (*Phoma terrestris* Hansen) lives and multiplies in the soil; consequently, it becomes more destructive the longer the onions are grown in the same field. It is disseminated on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

When pink root becomes serious on a given area the best procedure is to practice long rotation. Slips or sets from pink root infested soil should be avoided. Good cultural practices and high fertility are helpful. Efforts are being made to develop satisfactorily resistant varieties.

FUSARIUM ROT

Fusarium rot is a widespread disease, but it seldom causes severe losses. In the Rocky Mountain irrigated valleys it sometimes reaches economic proportions.

Rapid dying back of the leaves from the tips when plants are approaching maturity is the first evidence of the trouble. Most of the roots are eventually rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them a semiwatery decay is found, advancing from the base of the scales upward. The rot progresses somewhat slowly, and many recent infections are unnoticed at harvesttime. Thus the disease becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

The causal fungi (*Fusarium* spp.) live in the soil. Infection of the plants is sometimes correlated with maggot injury. Invasion occurs through wounds or in the vicinity of old root scars at the base of the bulb. The disease is favored by high soil temperatures, which is probably the chief reason for its appearance in the Northern States after midseason and for its more common destructiveness in the western valleys, where high temperatures are not unusual.

Careful sorting at harvest is recommended. Rotation is necessary when this disease becomes troublesome (fig. 7).

RUST

Two distinct rusts have been noted in North America upon the Egyptian perennial onion (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri* (Sow.) Wint., has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus rust fungus (*Puccinia asparagigi*

FIGURE 7.—Fusarium rot. Decay starts at the base of the scales and causes the leaves to die back from the tips; the bulb continues to rot in storage and in transit.

DC.), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears before midseason on leaves and seed stems as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or aecia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of *Botrytis* very similar to or identical with one of those causing neck rot of onion (p. 18), commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE ROT

White rot, a disease serious on onion, garlic, shallot, and leek, has been reported in northeastern Oregon, near Norfolk, Va., and near Louisville, Ky. It is known to be widespread in Europe, where it is very destructive on onion and leek in the British Isles and on garlic in Italy and Spain. Since onion and garlic are imported from Europe annually this disease may be introduced again at any time. Any outbreak of the disease upon onion, garlic, or closely related plants answering to the following description should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture.

White rot first appears usually during the cool, moist weather in the spring and autumn. The first signs are yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus *Sclerotium cepivorum* Berk., which inhabits the soil and invades the roots and the basal portions of the bulb scales (fig. 8). If diseased plants are gently pulled, they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a

white fluffy mass of fungus threads. Somewhat later this fungus mass takes on the appearance of a closely fitting weft in which are embedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds. The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages this disease might easily be confused with fusarium rot (p. 11), but in the latter no black sclerotia are ever formed. In the later stages white rot may be mistaken for neck rot (p. 18). In the latter disease black sclerotia are commonly formed. The neck rot sclerotia, however, are several times larger than those of the white rot; moreover, a gray mold is commonly associated with neck rot, while the mold associated with the other disease is distinctly white. Neck rot almost always appears after harvest and starts in most cases at the neck. White rot commonly appears on the growing crop, and infection occurs in the roots and bases of the scales.

The parasite is disseminated chiefly by bulbs that have come from diseased soil. Once established, the parasite may persist in the soil indefinitely and is known to survive northern winters. Bulbs from a diseased field should never be used for propagation, and soil once infested should not be used again for onions or closely related plants without being first steam-sterilized. In fact, any centers of the disease that are found should be reported at once and the area sterilized, if practicable, to avoid further spread.

FIGURE 8.—Onion white rot. Onion plant grown in diseased soil. Note that the entire root system has been destroyed and that the bases of the scales are also affected. The small, spherical black sclerotia which develop upon the diseased tissue are characteristic. As a result of the destruction of the basal portion of the plants the tops turn yellow and gradually die.

YELLOW DWARF

Yellow dwarf was first recognized in a destructive form in the Pleasant Valley district of Iowa in 1928. It had occurred to some extent in that district in 1927 and since then has been found in a few other States. It is most serious on the crop grown from onion sets and upon seed plants. The outstanding symptoms are severe stunting of the plants and in seed plants dwarfing and twisting of the seedstalks. The affected leaves and stems change from their normal green to various degrees of yellowing, extending from a few streaks to almost complete yellowing. It is said to have caused a 25-percent loss of the crop in the Pleasant Valley district in 1928. Since that time effective means of control have been perfected.

Yellow dwarf is a virus disease, which means that it is transmissible and infectious, but the contagious entity or virus is ultramicroscopic and not identifiable in the form of a bacterium or fungus. The virus lives over in bulbs of infected plants. When such bulbs or sets are

planted, the next year the plants are diseased and contain the virus throughout the leaves. The virus is then carried to surrounding healthy plants by plant lice, and thus the contagion may spread rapidly during the growing season. Yellow dwarf is not serious where the crop is grown from seed only, since the virus is not carried in the seed. Where bulbs are carried over as sets or for the propagation of seed in proximity to onions from seed there is opportunity for continual carry-over and propagation. It is under such conditions that yellow dwarf has become very serious.

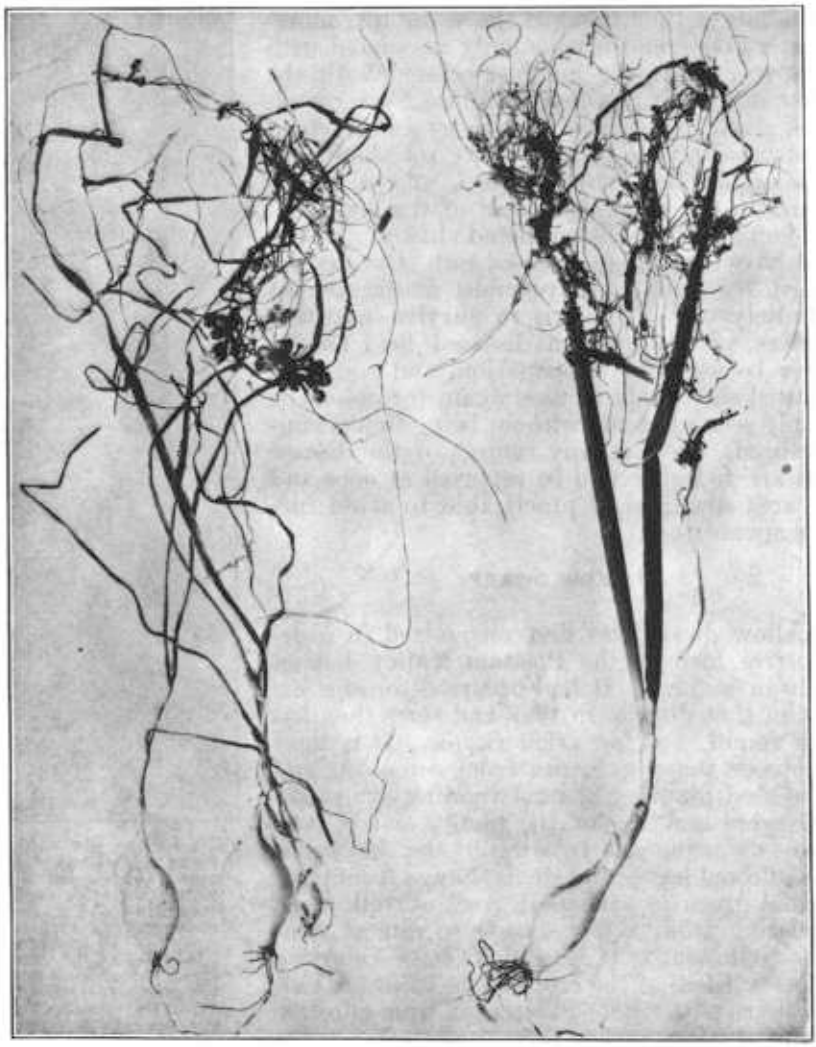


FIGURE 9.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending suckers into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants.

Onion sets should not be grown in proximity to a bulb crop grown from sets of the previous year or to a seed crop. In this way carry-over of the virus is limited. Onion sets can be indexed in the greenhouse during the winter months for the presence of the yellow dwarf virus.

DODDER

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the previously mentioned fungus parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil and are introduced in the spring with the onion seeds. The young dodder plant thus starts off just as the onion seedling does. It has no leaves, and its tendrillike stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue (fig. 9). After having thus become established as a parasite, the dodder gets most of its food from the onion and gradually sends out its tendrils to attack nearby plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers, and by the end of the season roughly circular areas of considerable size may occur in which the onion tops have been completely killed. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed. Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and, doubtless, it is likely to occur in any onion section.

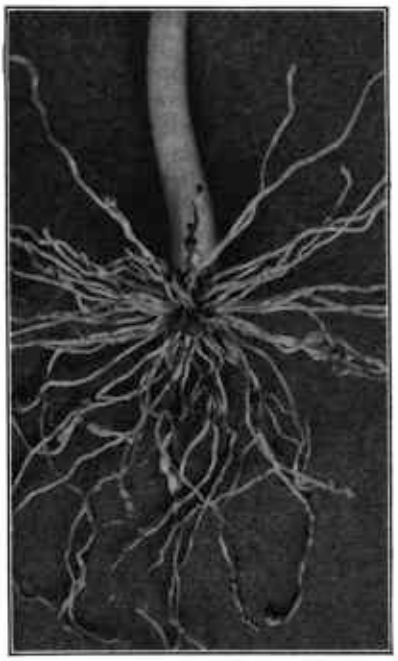


FIGURE 10.—Onion root knot, caused by an eelworm. Note that certain roots contain spherical or irregular swellings, from some of which small dark masses (the eggs) are protruding. Many active larvae of the eelworm escape from these egg masses into the soil and render it unfit for growing onions, as well as many other crops.

ROOT KNOT

Root knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in figure 10. The above-ground parts of badly diseased plants are dwarfed, the leaves are a sickly pale-green color, and the bulbs are reduced in size. Root knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of

the United States, has been reported only occasionally on onions, and fortunately there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm or nematode (*Heterodera marioni* (Cornu) Goodey), which lives in the soil and penetrates the onion roots, where swellings are produced. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvae), thus completing the life cycle.

When soil becomes infested with root knot eelworms it should be planted for 2 or more years with crops not subject to this nematode before a susceptible crop is grown. A list of resistant crops that may be used in rotation is given in Farmers' Bulletin 1345.

STEM NEMATODE

A strain of the bulb nematode (*Ditylenchus dipsaci* (Kühn) Filipj) which occurs on hyacinth and tulip is specialized on onion. It has been found only rarely in this country. An outbreak in New York State was eradicated in 1932. Any occurrence of this malady should be reported at once to the United States Department of Agriculture or to the State experiment station.

FARM PRACTICE IN RELATION TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth and, on going into its dormant state, becomes more susceptible to the attack of storage rot fungi and bacteria, which are continually present in the soil and on dead refuse.

While becoming dormant, the bulbs must be allowed to sweat or cure, preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture that is given off. Thus, if the weather remains clear and dry during harvesting and curing, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck rot (p. 18) and soft rot (p. 20), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck rot (p. 18), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest or the field should be plowed promptly. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not used for growing onions.

HARVESTING

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly, it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or stiff necks. These should not be placed in storage, but should be sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms that cause decay. The milling of sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvesttime to throw out all bulbs that show any signs of disease or insect injury. Although smut (p. 3) and mildew (p. 7) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage rot organisms. Fusarium rot (p. 11), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft rot and neck rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING

Onions are sometimes allowed to cure in windrows in the field, and if the weather is clear, yellow and red varieties can be handled successfully in this manner. In certain sections where intense sunlight is likely to cause sunburning or scorching of the outer scales it is essential to arrange the plants after pulling so that the bulbs are in every case covered by a layer of tops. It is preferable. however, to

place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties to damp weather in the field will almost invariably prove disastrous; they should be placed in a curing shed where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls and roof constructed to afford good insulation. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results. The best relative humidity for storage is about 65 percent.

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where globe onions are grown most extensively, yellow and red varieties are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck rot and smudge, and handling them successfully requires much more care during harvest and curing. In the onion-set growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion districts of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest because of their poor keeping quality and the lack of cold-storage facilities. In Louisiana the Creole variety is the favorite, because it resists the attacks of fungi and bacteria in storage and in transit much more effectively than the white and yellow Bermuda varieties.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK ROT

Neck rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 percent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties (fig. 11).

CHARACTERISTICS

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound. There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray, feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 11 and 12). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties are infected most readily, while the colored types more often escape it.

FIGURE 11.—Onion neck rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black, kernellike masses on the surface.

FIGURE 12.—Onion neck rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales.

THE CAUSAL ORGANISM

Neck rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds that attack lettuce, cabbage, and numerous other vegetables. These fungi are

not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotted scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination of air currents. They are thus carried to the healthy bulbs, where they germinate and send fungus threads into the necks, either through the dead tops or through wounds left by the removal of tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernellike bodies, or sclerotia, are compact masses of fungus threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

FIGURE 13.—Section through a bulb affected with soft rot. Beginning at the neck, the tissue is water-soaked and later becomes soft and slimy, giving rise to an offensive sulphurous odor. The rot advances down those scales which happen to become infected at the neck but does not go readily from scale to scale.

CONTROL

Proper care of the crop during harvest and curing is the chief measure of control for neck rot (p. 18). Avoid exposure to damp weather and provide cool, dry storage. White varieties should receive special attention, as they are very susceptible to the disease. Proper sanitation (p. 17) is also very important and worthy of careful consideration in connection with this disease.

Artificial curing of white onion sets is advisable when curing weather is unfavorable and neck rot has started to appear. This requires special equipment and is not ordinarily economical for the average grower, but may be advantageous to the dealer who contracts for sets for storage and shipment. The sets are placed in a kiln in the shallow slatted crates in which they are ordinarily cured. Warm air at 100° to 120° F. is forced through them by a blower for several hours, until the neck tissue is thoroughly dry. If the neck rot fungi have not advanced very far, the desiccation of the scale tissue checks their advance completely.

SOFT ROT

Soft rot usually begins at the neck of the bulb, advancing down one or more scales (fig. 13). It sometimes starts in bulbs in the field slightly before harvest. The tissue is at first water-soaked; later it disintegrates into a soft slimy mass. An offensive sulphurous odor is usually given off, a characteristic that serves to distinguish it from

other bulb decays. The decay does not pass readily from scale to scale. It may start at bruises or wounds on the scales and commonly follows in tissue injured by freezing. When the rot affects only one or two inner scales, as is often the case, the only external sign of the disease is the lack of firmness of the bulb and often the appearance of a watery exudate through the neck when pressure is applied to the upper part of the surface of the bulb.

Soft rot differs from the disease discussed previously in that the causal organism (*Bacillus carotovorus* L. R. Jones) is one of the bacteria rather than a fungus. It is the same one which causes soft rot of other vegetables, such as cabbage, carrot, and celery. The organism is widespread in its occurrence but invades usually dormant storage parts of the plant and enters only through wounds and in moist environment. Maggot larvae may carry the bacteria and through their feeding on bulbs provide the necessary wounds for infection. The bacteria may persist in the intestinal tract of the larvae and the adult fly and thus be carried from place to place. The eggs may be contaminated when laid by the fly, and thus the soft rot bacteria become identified closely with the life history of the maggot, depending upon the latter for its perpetuation and dissemination.

The precautionary measures already recommended on pages 17 and 18 regarding harvesting, curing, and storing should be followed carefully.

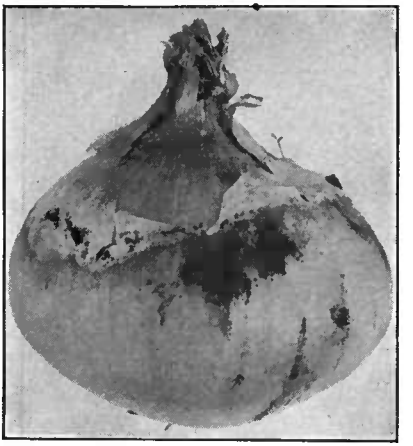


FIGURE 14.—Black mold. Irregular sooty masses occur on the outside of the scales or between them. The outer scales shrivel about the neck of the bulb and assume a brittle papery texture. Compare with onion smut.

BLACK MOLD

Black mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and California, however, it is one of the most important storage and transit diseases.

Because of its resemblance in appearance, black mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black mold are borne on the exterior of the scales and can be rubbed off readily (fig. 14). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it. While most

conspicuous on white varieties, it occurs commonly on all colored-bulb varieties.

The causal organism (*Aspergillus niger* Tiegh.) is a very common saprophyte, living on almost any dead or dying vegetable matter. Where it is most serious on onions it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but it is not noticeable until the onions are pulled. Rainy weather at this critical period will result in widespread infection, which continues to develop in storage and transit.

To hold black mold in abeyance general sanitary measures and protection from moisture after harvest are essential. Bulbs should be thoroughly dry before being shipped, since moisture in the pack favors rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage, in order to hold the disease in check.

FIGURE 15.—Onion smudge. Black smudgy spots made up of small black dots occur on the outer scales of white varieties. There is a slow invasion of the fleshy scales.

SMUDGE

Onion smudge is confined largely to white varieties. It appears in the field just before harvesttime and continues to develop during the storage period. It is characterized by small, dark-green to black dots, which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (fig. 15). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, the chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

The causal fungus (*Colletotrichum circinans* (Berk.) Vogl.) lives over between seasons on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown in the same fields year after year. It is widely distributed through the trade on white onion sets and by this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots, on which myriads of minute spores are produced (fig. 15). These

spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

Susceptibility to this disease and to neck rot has greatly reduced the acreage of white varieties in northern areas. Special care at harvesttime is necessary in handling them. The crop must be harvested promptly, exposure to rain avoided if possible, and rapid and thorough curing insured. Artificial curing is helpful, but it is seldom necessary except with onion sets in which neck rot also threatens to develop.

ASPERGILLUS ROT

Aspergillus rot is a decay of garlic bulbs which has been found twice on imported stock. The scales are reduced to a rather dry powdery condition, and through the mass are brown kernels (sclerotia) two or three times the size of the head of a pin. The causal fungus (*Aspergillus alliaceus* Thom and Church) commonly fruits on the surface as a lemon-yellow mold, similar except in color to black mold. The fungus, though never found on the onion as yet, readily decays onion bulbs when it once gains entrance. The sclerotia are somewhat larger and browner than those of the white-rot organism and smaller than those of the neck-rot fungi. Attention is called to its occurrence, since it is likely to be found on the onion at some future time. The parasite works only at somewhat high summer temperatures and thus will not be serious as a rot in cold storage.

NONPARASITIC BLEMISHES AND MALADIES

FREEZING INJURY

Occasionally onions are subjected to freezing temperatures. Growing plants may be killed if the temperature is low enough and lasts long enough. The Bermuda and Sweet Spanish varieties are much more susceptible than the Globe varieties. The first-named types are also more likely to show a larger percentage of doubles and multipliers among the plants that survive freezing in the field.

Bulbs exposed to freezing temperatures in the field, in storage, or in transit will show freezing injury. The average freezing temperature for onions of the globe type is about 30° F. It is possible to cool them below the freezing point without injuring them. If they are handled or moved in the undercooled condition, ice formation in the tissues occurs and damage sets in. Undercooled bulbs suffer less damage if they are thawed out at 50° or above than if thawed slowly at 32°.

Freezing injury can be determined by cutting the bulb longitudinally or transversely. The affected tissue is water-soaked, discolored, and more or less transparent, having indefinitely scattered opaque areas. Freezing injury is easily confused with physiological breakdown discussed on page 24. It is not uncommon to find some scales injured and others not, because of the fact that the freezing point of

the tissues varies. Thus the outer scale may be injured, the next one sound, the third injured, the next sound, and so on. Soft rot commonly follows the freezing injury. If it is confined to the outer scales, the bulbs can usually be salvaged by being spread in thin layers and allowed to dry out.

PHYSIOLOGICAL BREAK-DOWN

Physiological break-down, an injury not unlike freezing injury in symptoms, sometimes develops after harvest in bulbs that have not been exposed to low temperatures. The scale tissue is discolored and water-soaked, and though more common on scales near the surface it may be found in deeper ones. The nature and cause of this injury is not known. It may be found in the market and in storage and may continue to develop during the storage period. For this reason it is likely to be confused with freezing injury, and it is, therefore, advisable to know the history of lots in question before final diagnosis is made.

CHEMICAL INJURIES

Blemishes of market onions which reduce their attractiveness are commonly encountered, especially in colored varieties. The color compounds in the scales are in the same general class as the chemist's color indicators, and therefore they respond accordingly to changes in acidity or alkalinity. A number of color blemishes occur that are caused by contact with alkaline materials. One of the most common of these is "alkali scorch" or "bag print." Dark-brown to black spots on yellow or red onions occur at points in which the bulbs come in contact with the jute-bag container, particularly if the bag has become moistened after being packed. Alkaline materials infiltrated in some bags are responsible for this. They occur in some lots of bags and not in others.

Another reaction of the same type is sometimes encountered in cold storage where leakage of ammonia fumes results in alkaline reaction of moisture on the surface of colored bulbs. Less than 1 percent of ammonia in the storage-room air will cause marked discoloration. A similar effect has been noted on stock covered with manure for protection from frost, in which case ammonia fumes arise from the manure. In all these cases the strength of the material, the amount of moisture on the bulb surface, and the duration of the exposure determine the extent of the injury.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Under Secretary	M. L. WILSON.
Assistant Secretary	HARRY L. BROWN.
Director of Extension Work	C. W. WARBURTON.
Director of Finance	W. A. JUMP.
Director of Information	M. S. EISENHOWER.
Director of Personnel	W. W. STOCKBERGER.
Director of Research	JAMES T. JARDINE.
Solicitor	MASTIN G. WHITE.
Agricultural Adjustment Administration	H. R. TOLLEY, *Administrator.*
Bureau of Agricultural Economics	A. G. BLACK, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	IRA N. GABRIELSON, *Chief.*
Bureau of Chemistry and Soils	HENRY G. KNIGHT, *Chief.*
Commodity Exchange Administration	J. W. T. DUVEL, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology and Plant Quarantine	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Farm Security Administration	W. W. ALEXANDER, *Administrator.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	FREDERICK D. RICHEY, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Soil Conservation Service	H. H. BENNETT, *Chief.*
Weather Bureau	WILLIS R. GREGG, *Chief.*

U. S. GOVERNMENT PRINTING OFFICE: 1937

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 5 cents